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STRENGTH PROPERTIES OF CONCRETE BY USING RED MUD AS A REPLACEMENT OF CEMENT WITH HYDRATED LIME

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ABSTRACT

The research was conducted to study the properties of concrete by using red mud as replacement of cement in concrete. The Bayer Process for the production of alumina from Bauxite ore is characterized by low energy efficiency and it results in the production of significant amounts of dust-like, high alkalinity bauxite residues known as red mud. Currently red mud is produced almost at equal mass ratio to metallurgical alumina and is disposed into sealed or unsealed artificial impoundments (landfills), leading to important environmental issues. It comprises of oxides of iron, titanium, aluminum and silica along with some other minor constituents. Presence of Alumina and Iron oxide in red mud compensates the deficiency of the same components in limestone which is the primary raw material for cement production. Presence of soda in the red mud which when used in clinker production neutralizes the sulfur content in the pet coke that is used for burning clinker enrooted cement production and adds to the cement's setting characteristics. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud management issues i.e. of utilization, storage and disposal. Different avenues of red mud utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible.

Experiments have been conducted under laboratory condition to assess the strength characteristics of the aluminum red mud. The project work focuses on the suitability of red mud obtained for construction. Five test groups were constituted with the replacement percentages 0%, 5%, 10%, 15%, 20% of red mud and 5% of hydrated lime with cement in each series in M_{40} and M_{50} grade concrete. To achieve Pozzolanic property of red mud, hydrated lime was added. This paper points out another promising direction for the proper utilization of red mud.

Key words: Cement mortars, Red mud, hydrated lime, monotonic load and Deflection.

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1. INTRODUCTION

1.1. General

Bayer's process for Alumina production uses Caustic and Bauxite as the main raw material for Alumina production and generates Red mud which practically doesn't have wide industrial application and is generally dumped as a non-value by product in the backyards of a Alumina Refinery called as Red Mud yard. Over the years the red mud produced were lying in the yard not without any usage. Huge space of about 3.0 acres needed per annum to store the Red Mud and dykes. But a breakthrough was made when MALCO discovered that red mud could be tried as an alternative for the Low Grade Bauxite (LGB) which the cement industries used for its cement production. An idea struck as why not try Red Mud in cement industries instead of Bauxite as the composition of both are almost similar. It's quite possible as the cement industries were on the look out to make up for the deficiency of Alumina, in their raw materials viz - Lime stone for Cement production.

Red mud is the industrial waste generated during the production of alumina. According to the grade of raw material bauxite and the production process of alumina, red mud can be divided into Bayer red mud and Sintering red mud Based on present technologies, there is 0.8~ 1.76 t red muds generated by each 1t alumina produced. It is reported that, there are up to 3 million tons of red mud produced by China's largest three alumina production bases (Guizhou, Shandong and Henan) . The main reaction that occurs in the Bayer process (the conversion of bauxite to sodium aluminate) can be schematized as follows:

1.2. Bayer Process

The Bayer process, as it has become known, is used for refining bauxite to smelting grade alumina (aluminum oxide), the precursor to aluminum. Typically, depending upon the quality of the ore, between 1.9 and 3.6 tons of bauxite is required to produce 1 tonn of alumina. The Bayer process is a cyclic one and is often called Bayer cycle. It involves four steps: digestion, clarification, precipitation, and calcinations.

1.3. Sinter Process

Sintering is a thermal treatment, below the melting temperature of the main constituent material, which transforms a metallic or ceramic powder (or a powder compact) into a bulk material containing, in most cases, residual porosity. The process of sintering brings about certain physical as well as chemical changes in the material.

2. PROPERTIES OF RED MUD

2.1. Physical Properties of Red Mud

The following are the physical properties of the mud powder.

- Generally fineness of red mud is varies between 1000-3000cm^2/gm.
- Its PH is varies in between 10.5 to 12.5 hence alkaline in nature
- Specific gravity of red mud is found to be 2.51

2.2. Chemical Properties of Red Mud

Chemical properties of red mud are shown in below table it indicates that percentage of Cao is vary less hence it has no cementitious properties but when it reacts with water and cements it starts gaining cementitious properties. And also to improve this property we adding the optimized percentage of lime (5%).

2.3. Composition of Red Mud and its Properties

Red Mud as such containing about 65% to 70% Solids with the remaining as moisture is a thixotropic substance which exhibits shear thinning behavior i.e., when the shear rate is increased, the apparent viscosity decreases. The following is the composition of the Dry Red Mud

Table 1 Composition of red mud

COMPONENTS	Al_2O_3	Fe_2O_3	SiO_2	TiO_2	CaO	Na_2O
WEIGHT %	20-22	40-45	12-15	1.8-2.0	1-2	4-5

3. OBJECTIVES OF THE STUDY

The major objectives of this study were:

- To identify various industrial wastes suitable for utilization in cement manufacture.
- To assess the compatibility of industrial solid waste as raw material/ blending material/ admixture.
- Physico-chemical and mineralogical characterization of industrial wastes.
- To examine the constraints related to utilization of industrial waste.
- To make recommendations to promote utilization of industrial waste.

4. MATERIALS

4.1. Materials Used

4.1.1. Cement

Ordinary Portland cement of 53 grade was used in this study. The cement was tested according to IS: 12269-1987.Different test were carried out on the cement to ensure that it confirms to the requirements of the IS: 12269-1987specifications. Cement is a binder, a substance used in construction that sets and hardens and can bind other materials together.

4.1.2. Fine Aggregates

It is the aggregate most of which passes 4.75 mm IS sieve and contains only so much coarser as is permitted by specification. According to source fine aggregate may be described as: For the present investigation, locally available river sand (coarse sand) conforming to Grading Zone II of IS 383:1970 was used as fine aggregate.

4.1.3. Coarse Aggregates

Hard crushed granite stone, coarse aggregates confirming to graded aggregate of size,10mm as per IS:383-1970 was used in the study According to size coarse aggregate is described as graded aggregate of its nominal size

4.1.4. Water

Fresh and clean water is used for casting and curing of specimen. The water is relatively free from organic matters, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard.

4.1.5. Hydrated Lime

We are known as a hydrated lime manufacturer, hydrated lime suppliers in India. Hydrated lime, also known as calcium hydroxide. Pure hydrated lime power is popularly known as calcium hydroxide or slaked lime. The controlled slacking of quicklime with water gives us white dry power then the released heat of reaction is captured and the extra slaking water is evaporated. The chemical formula of our pure hydrated lime is $Ca(OH)_2$.Hydrated lime having higher percentage of calcium hydroxide (90%) over low grade (65% purity) hydrated lime.

4.1.6. Red Mud

Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminum industry's most important disposal problems. The red colour is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. In addition to iron, the other dominant particles include silica, unbleached residual aluminum, and titanium oxide. Red mud cannot be disposed of easily. As a waste product of the Bayer process the mud is highly basic with a pH ranging from 10 to 13. The specific gravity is 2.64.

5. TEST PROCEDURE

5.1. Compressive Strength

5.1.1. Test Specimens

Totally 120 cubes (60 for M_{40} +60 for M_{50}) of size 150 mm x 150 mm x 150 mm and were cast to study the compressive strength of red mud concrete. Standard cast iron moulds were used for casting the test specimens.

Figure 1 Compressive strength of red mud concrete equipment

5.2. Split Tensile Strength

5.2.1. Test Specimens

Totally 60 cylinders (30 for M_{40} and 30 for M_{50}) having a diameter of 150 mm and 300 mm length were cast to evaluate the split tensile strength of red mud concrete. Standard cast iron moulds were used for casting the test specimens.

Figure 2 Split tensile strength of red mud concrete equipment

5.3. Flexural Strength

5.3.1. Test Specimens

Totally eighteen prisms of size 500mmx100mm x100 mm were cast to study the flexural strength of red mud concrete. Standard cast iron moulds were used for casting the test specimens.

Figure 3 Flexural strength of red mud concrete equipment

6. RESULTS AND ANALYSIS

6.1. Slump Cone Test

The test measures consistency of concrete in that specific batch. It is performed to check consistency of freshly made concrete. Consistency refers to the ease with which concrete flows. It is used to indicate degree of wetness

Table 2 Slump cone test results

% replacement of cement	Hydrated lime (%)	Slump value (mm) M40	Slump value (mm) M50
00	5	25	27
05	5	26.5	28.5
10	5	27	30
15	5	28	32
20	5	29	34

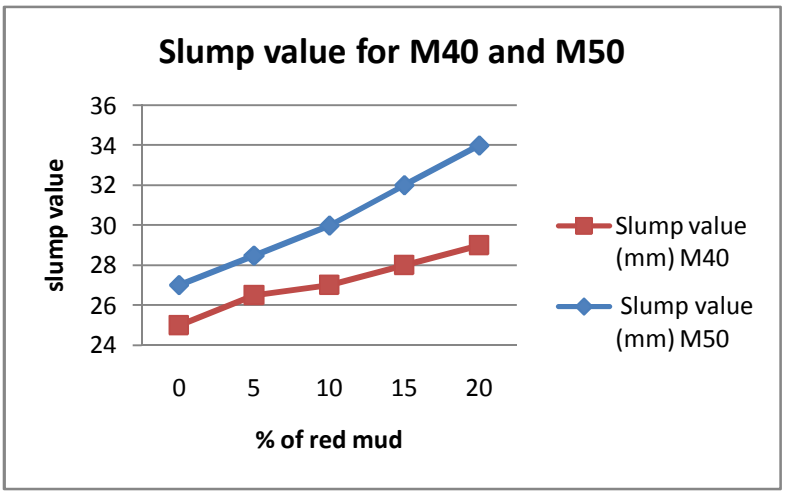

Figure 4

6.2. Compaction Factor Test

Compaction factor test is primarily design as laboratory test but if required this test can be done in field also. Compared to slump test, Compaction factor test is more sensitive and accurate. This test is suitable for concrete mixes of very low workability.

Table 3 Compaction factor test

% replacement of cement	Hydrated lime (%)	Compaction factor for M40 grade	Compaction factor for M50 grade
0	5	0.86	0.87
5	5	0.88	0.89
10	5	0.91	0.91
15	5	0.93	0.93
20	5	0.94	0.95

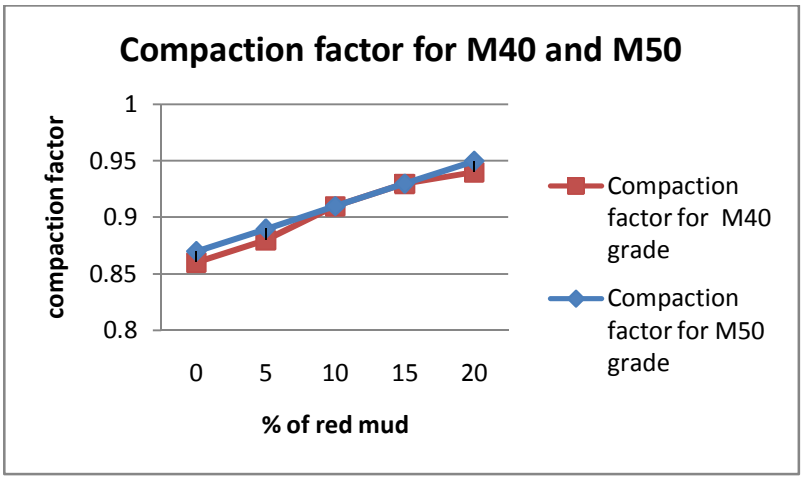

Figure 5

Table 3 Compressive strength of concrete without hydrated lime

S.no	% red mud used	7 days compressive strength for M40 grade	28 days compressive strength for M40 grade	7 days compressive strength for M50 grade	28 days compressive strength for M50 grade
1	0%	29	51	35	62
2	5%	31	53	37	63.5
3	10%	33	55	39.5	66
4	15%	26	44	32	58
5	20%	22	38	28	52

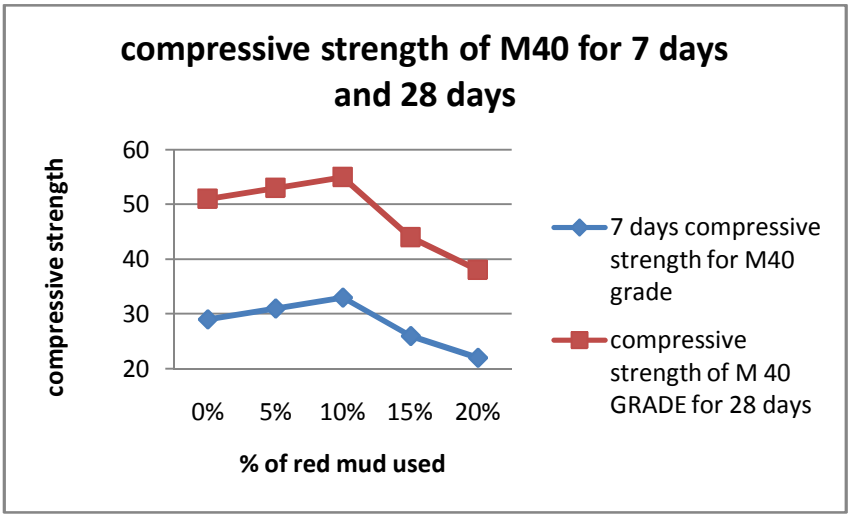

Figure 6 Compressive strength of M40 grade concrete without hydrated lime

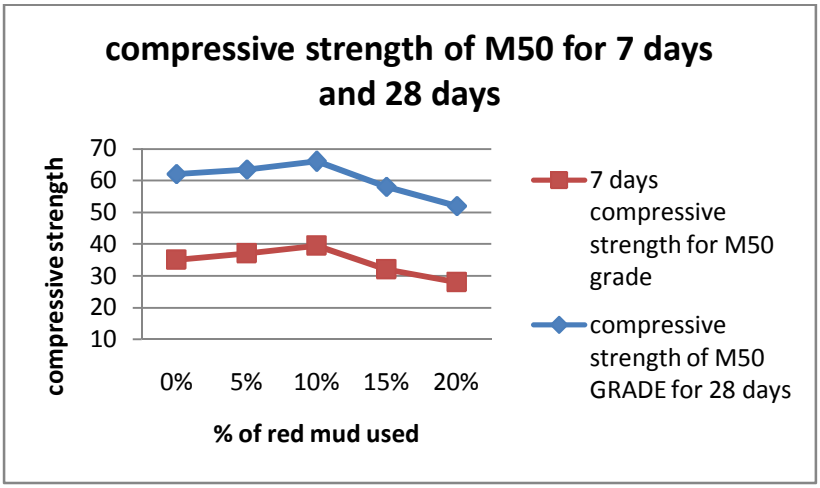

Figure 7 Compressive strength of M50 grade concrete without hydrated lime

Table 4 compressive strength of concrete with 5 % hydrated lime

S.no	% of red mud	7 days compressive strength for M40 grade	28 days compressive strength for M40 grade	7 days compressive strength for M50 grade	28 days compressive strength for M50 grade
1	0%	30	51	36	62
2	5%	32	54	38	64
3	10%	35	56	42	66
4	15%	24	48	34	52
5	20%	20	42	30	48

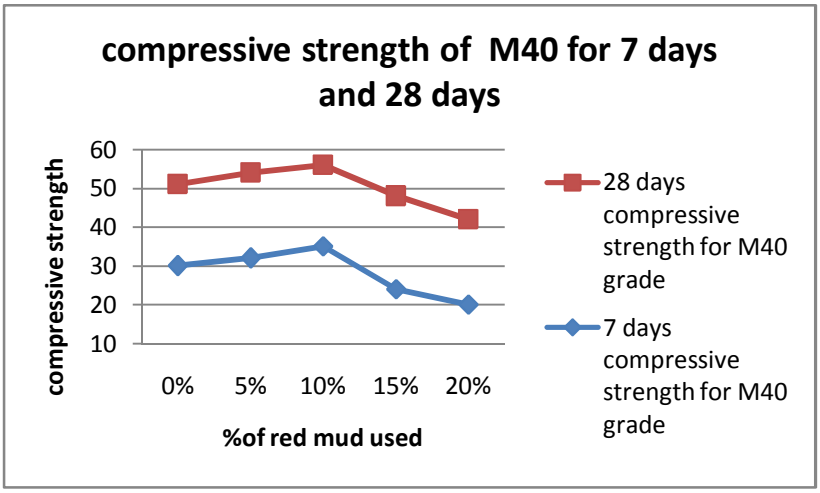

Figure 8 Compressive strength of M40 grade concrete with 5% hydrated lime

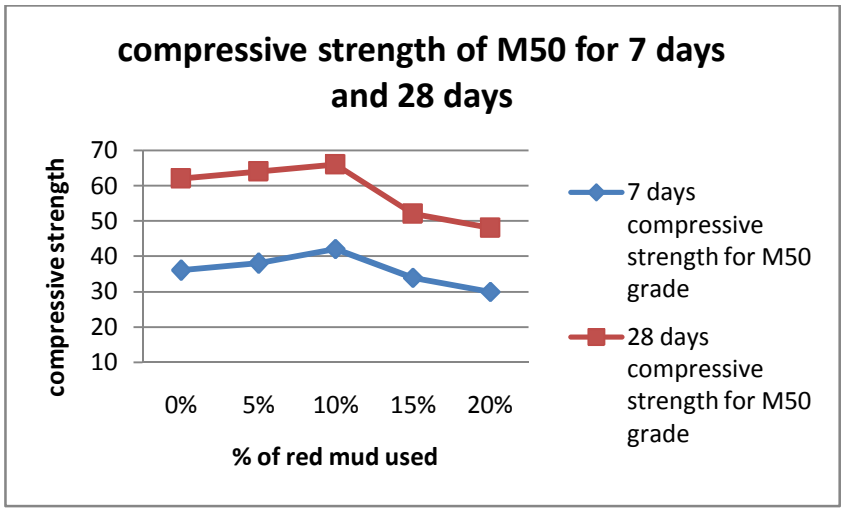

Figure 9 Compressive strength of M50 grade concrete with 5% hydrated lime

6.3. Split Tensile Strength of Concrete

Table 5 Split tensile strength of concrete

S.no	% red mud used	28days split tensile strength without hydrated lime for M40 grade	28days split tensile strength with 5% hydrated lime for M40 grade	28days split tensile strength without hydrated lime for M50 grade	28days split tensile strength with 5% hydrated lime for M50 grade
1	0%	5.1	5.1	6.2	6.2
2	5%	5.3	5.4	6.3	6.4
3	10%	5.4	5.6	6.6	6.6
4	15%	4.4	4.8	5.8	5.2
5	20%	3.8	4.2	5.2	4.8

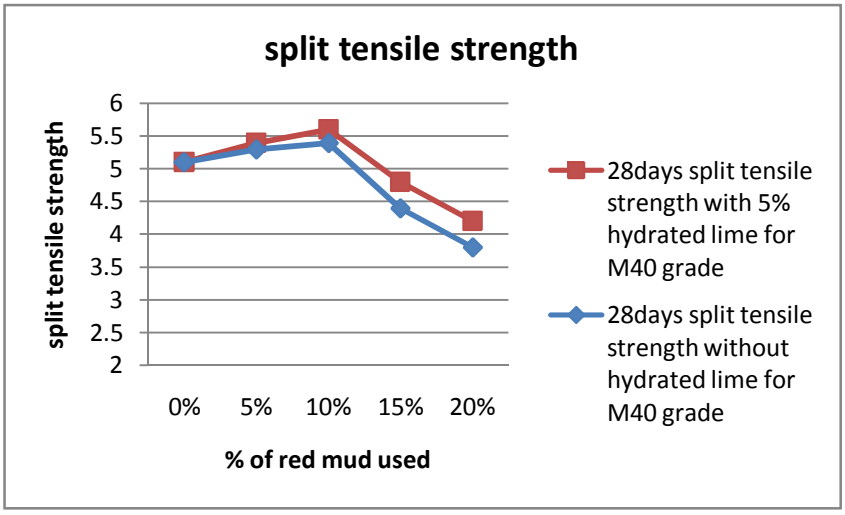

Figure 10 Split tensile strength of concrete for M40 grade

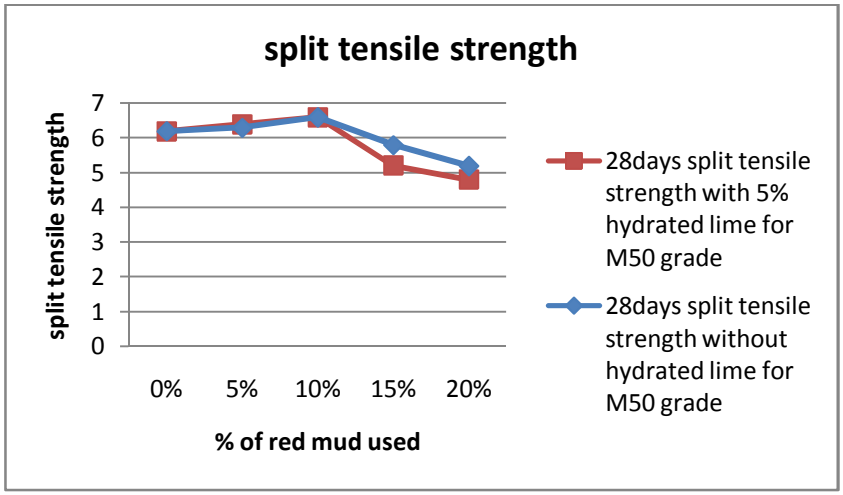

Figure 11 Split tensile strength of concrete for M50 grade

6.4. Flexural Strength of Red Mud Concrete

Table 6 flexural strength of red mud concrete

S.no	% red mud used	28days flexural strength without hydrated lime for M40 grade concrete	28days flexural strength with 5% hydrated lime for M40 grade concrete	28days flexural strength without hydrated lime for M50 grade	28days flexural strength with 5% hydrated lime for M50 grade
1	0%	7.12	8.26	8.92	10.12
2	5%	5.26	5.82	6.4	7.52
3	10%	4.61	4.56	5.68	6.74
4	15%	3.91	4.32	5.2	6.32
5	20%	3.26	3.62	5.1	5.2

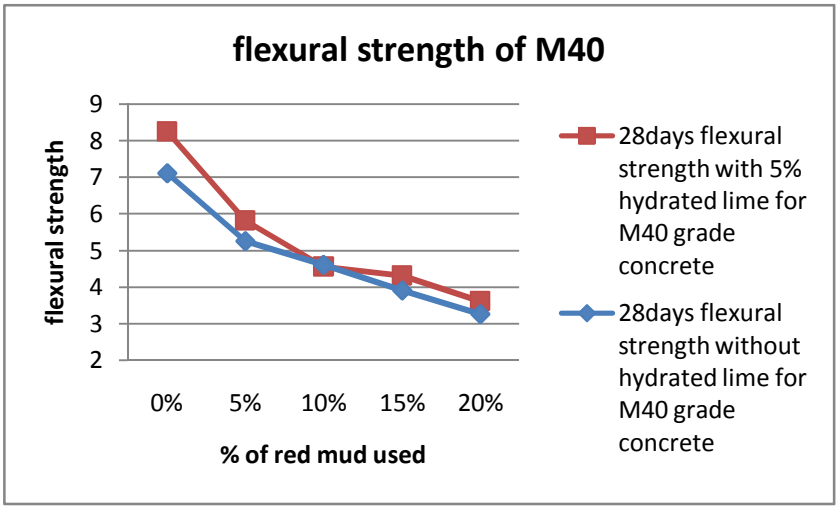

Figure 12 Flexural strength of M40 grade concrete

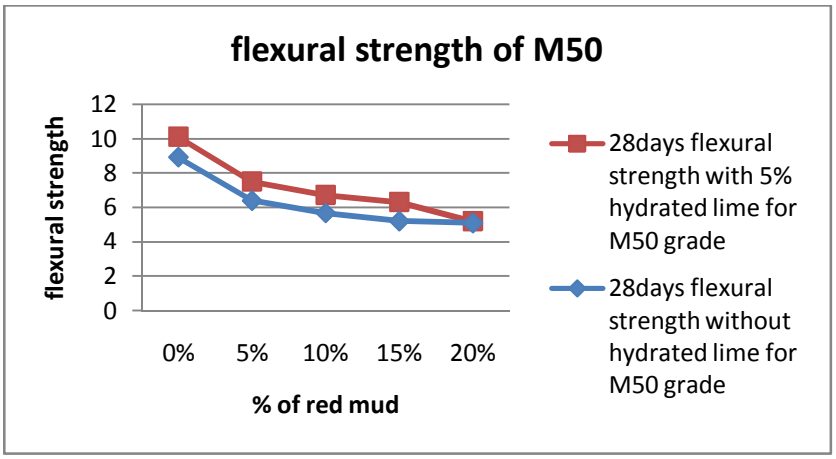

Figure 13 Flexural strength of M50 grade concrete

7. CONCLUSIONS

From this research the following conclusions are:

- The slump value is increasing with increase in the percentage of red mud in concrete for 5% hydrated lime. Due to increase in the red mud leads to decrease in the quantity of cement results in increase in the workability of concrete.
- The compressive strength of M40 for 28 days at 0%,5%,10%,15%,20% is 51kN/m^2,53 kN/m^2,55 kN/m^2 ,44 kN/m^2, 38 kN/m^2 respectively.
- The compressive strength of M50 for 28 days at 0%,5%,10%,15%,20% is 62kN/m^2,63.5 kN/m^2,66 kN/m^2 ,58 kN/m^2, 52 kN/m^2 respectively.
- The compressive strength of M40with 5% hydrate lime for 28 days at 0%,5%,10%,15%,and 20% is 51kN/m^2,54 kN/m^2, 56 kN/m^2, 48 kN/m^2, 42 kN/m^2respectively.
- The compressive strength of M50 with 5% hydrated lime for 28 days at0%,5%,10%,15%,20% is 62kN/m^2,64 kN/m^2,66 kN/m^2 ,52 kN/m^2, 48 kN/m^2 respectively.
- The optimum value of the compressive strength of red mud concrete for 7 days curing was observed at 10% red mud replacement. And also for 28 days compressive strength observed at 10% red mud replacement .The compressive strength of concrete using 5% hydrated lime is more as compared with the concrete without hydrated lime.
- The optimum value of split tensile strength by using hydrated lime and without using hydrated lime are observed at 10% red mud replacement. And also split tensile strength is high for 5% hydrated lime concrete.
- The optimum value of flexural strength was observed at 0% replacement of red mud concrete for both using hydrated lime and without using hydrated lime at 28days of curing. The percentage economy is increased with the increase in the grade of concrete but at the same time there is a reduction in the percentage increase in the Compressive Strength.
- Red mud can be effectively used as replacement material for cement and replacement enables the large utilization of waste product. Red mud did not effect of the cement properties, rather improved the cement quality by way reducing the setting time & improved compressive strength. Physical parameters of red mud are affected by calcination process
- The surface area and the unitary mass decrease and the specific gravity increases, The results of pozzolanic activity by chemical and physical methods were very satisfactory and indicate the feasibility of red mud use as a pozzolan, in addition to Portland cement

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